

P-OP-08

The Characterization of the Witness Sample testing for the Outgassing Qualification of EUV Resists



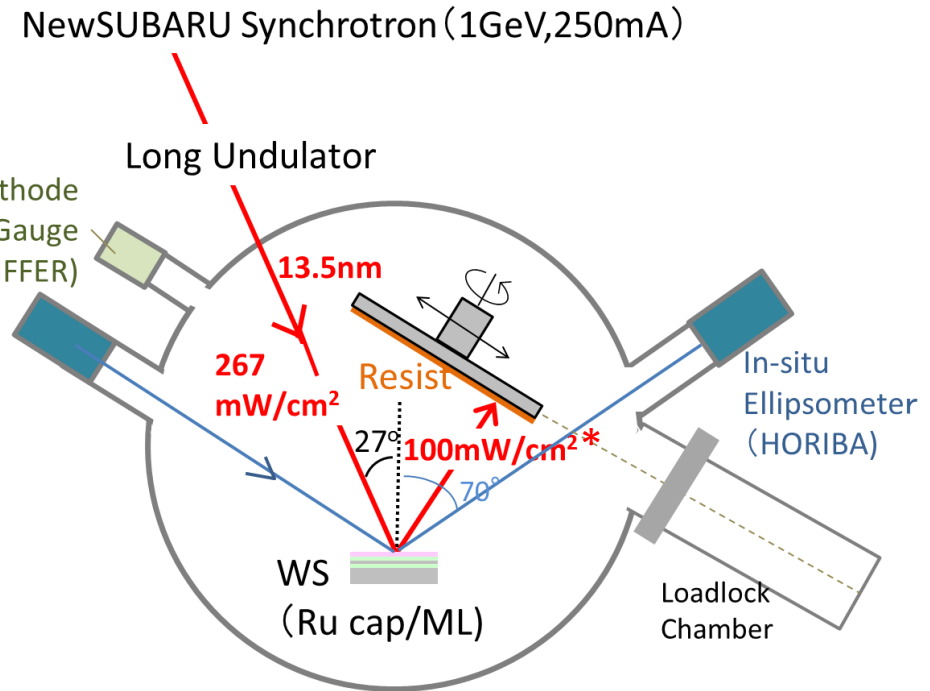
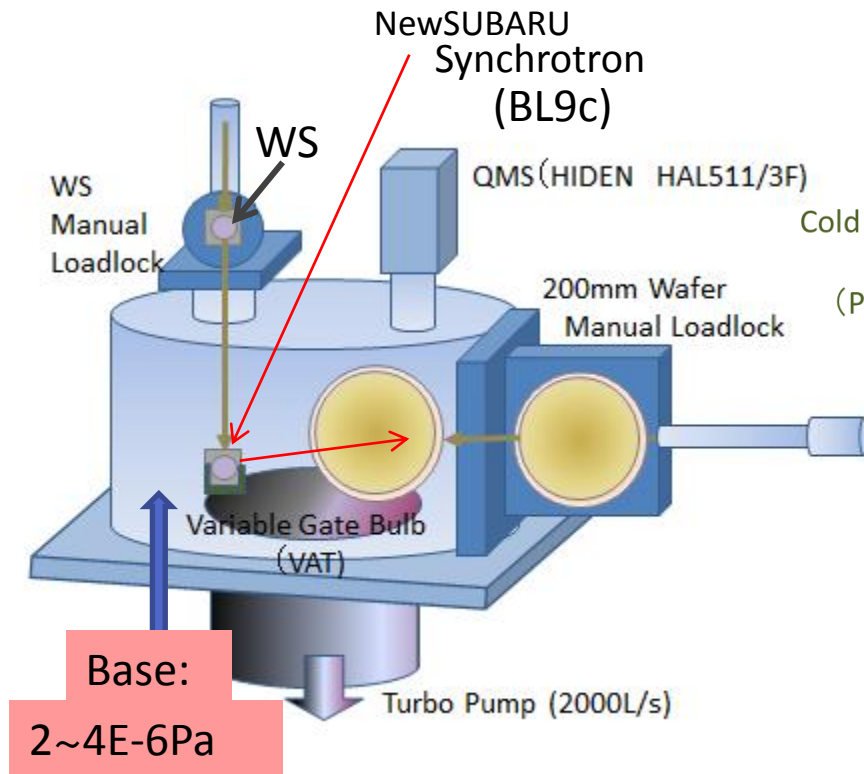
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Objective of this Work

- **Verify the feasibility of HERC (High power EUV Resist Contamination) analysis tool of EIDEC.**
- **Investigate the parameter of EUV exposure condition which relates to the contamination growth (CG) on the Witness Sample (WS).**
- **Examine the effects of resist components to the CG.**

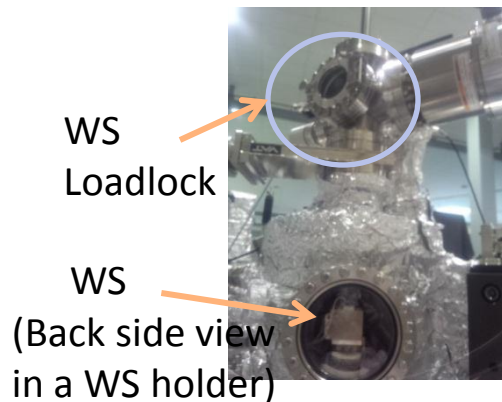
HERC (High power EUV Resist Contamination) analysis tool



* calculation for the WS with average surface roughness

Side View

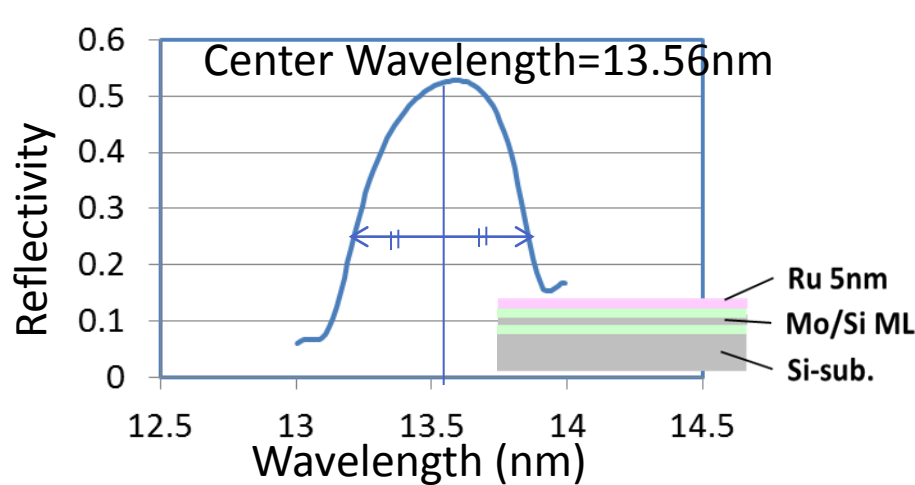
Top View



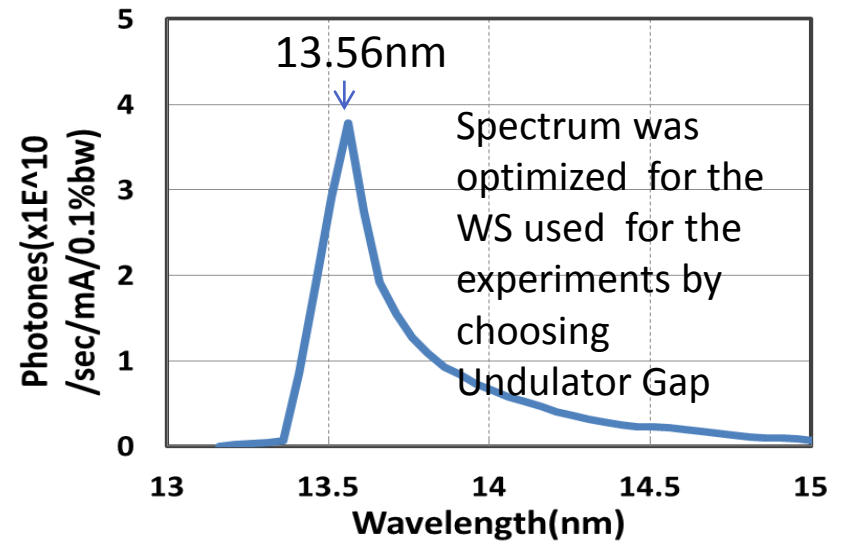
In situ ellipsometer (source unit)



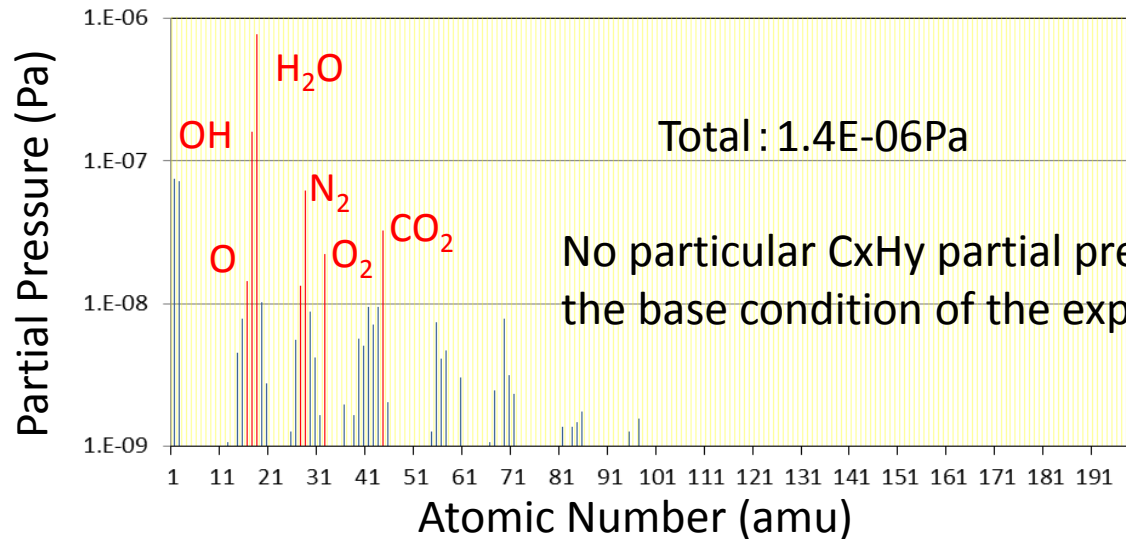
Illumination setup of Witness Sample (WS)



Witness Sample Reflectivity
(Measured by Reflectometer at BL10)

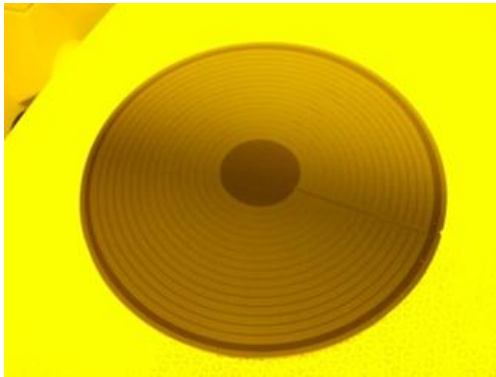


BL9c EUV Spectrum exposed on Witness Sample



Base Partial Pressure of HERC chamber

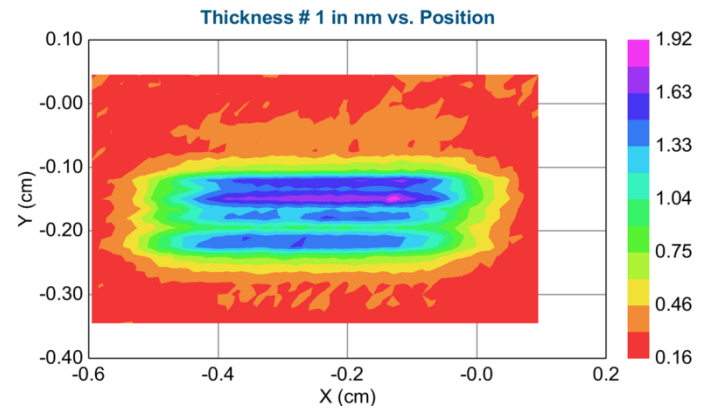
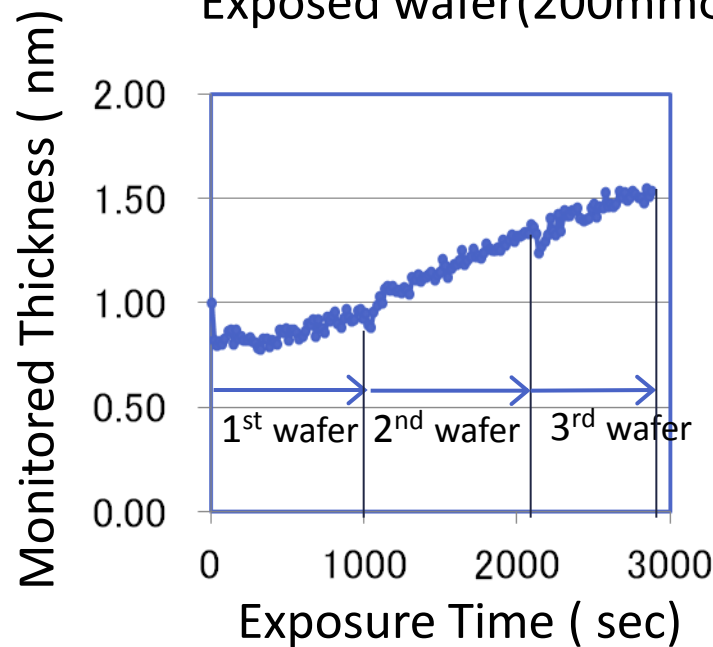
Exposed resist and observed contamination on Witness Sample



Exposed wafer(200mm ϕ)

86% area of a 200mm ϕ is exposed by moving wafer stage relative to the synchrotron beam

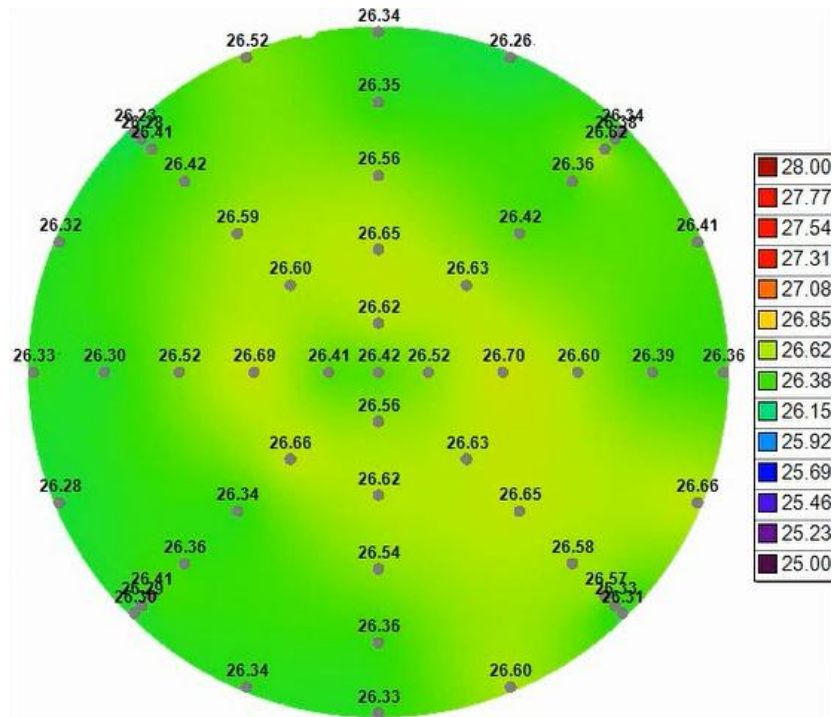
➔ **2.7x200mm ϕ wafers were exposed for the equivalent area of 1x300mm ϕ full wafer.**



Offline SE measurement of Carbon contamination by Woollam M-2000X

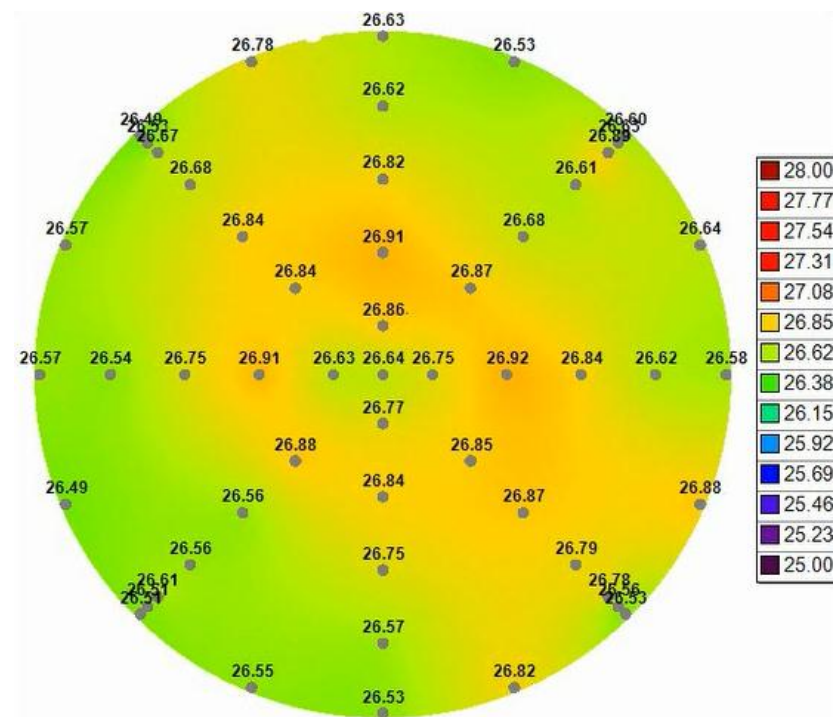
Carbon contamination thickness measured on a WS during exposure by in-situ ellipsometer

Wafer temperature during exposure



Mean : 26.54
3-sigma : 0.40
Range : 0.45

+0.25 °C

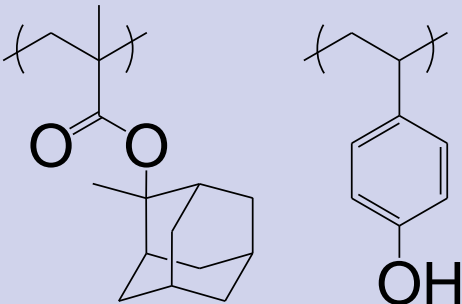
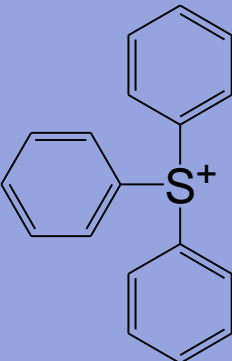
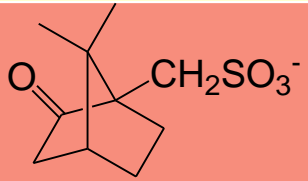


Mean : 26.79
3-sigma : 0.40
Range : 0.43

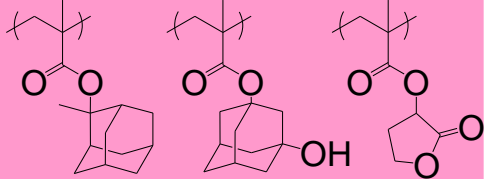
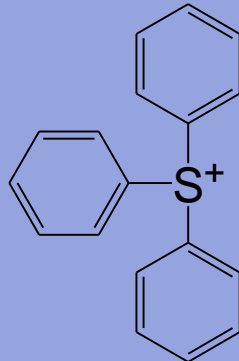
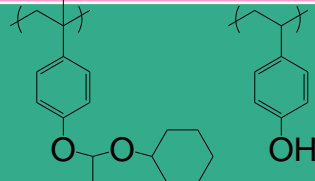
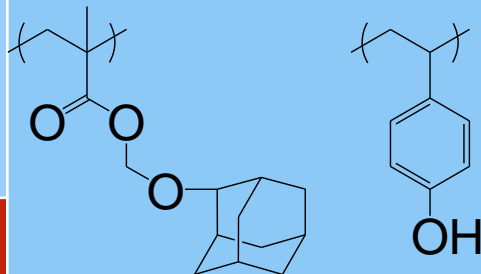
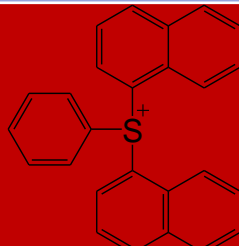
At the beginning of the exposure

After 20 min. of exposure

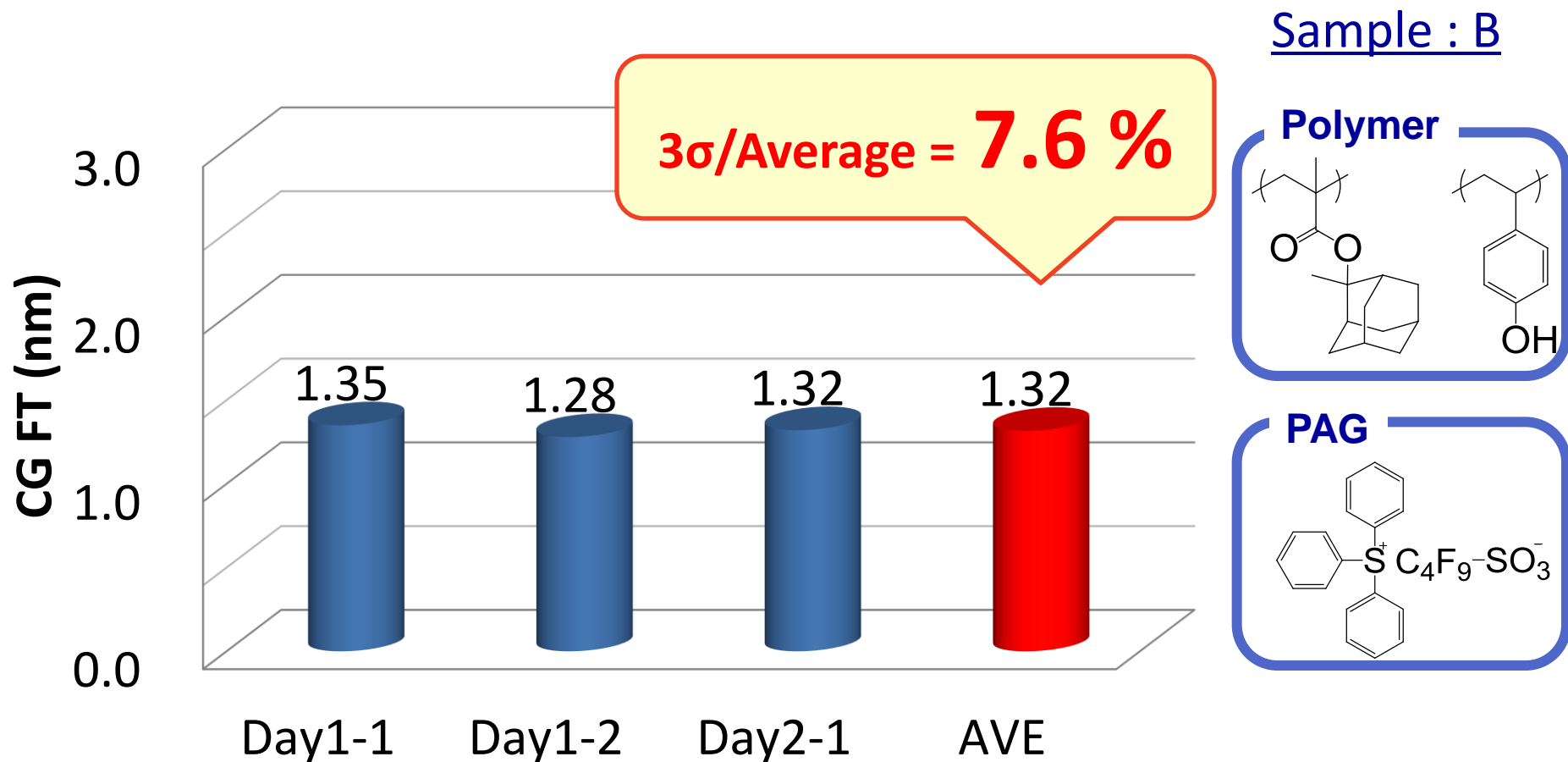
Wafer Temperature change was negligible during the exposure.

Sample	Polymer	PAG cation	PAG anion (Relative size)	Sensitivity (mJ/cm ²)
A			CF ₃ SO ₃ ⁻ (1.0)	5.4
B			C ₄ F ₉ SO ₃ ⁻ (2.1)	4.7
C			 (2.9)	6.5
D			Bulky anion (3.6)	5.2

Evaluated Resists (II) Polymer and PAG Cation Variation

Sample	Polymer	PAG cation	PAG anion (Relative size)	Sensitivity (mJ/cm ²)
E	 Methacrylate	 Small cation	C ₄ F ₉ SO ₃ ⁻ (medium size)	6.4
F	 PHS			4.9
G	 PHS-Methacrylate Hybrid			3.1
H				

Reproducibility of Contamination Growth (CG)



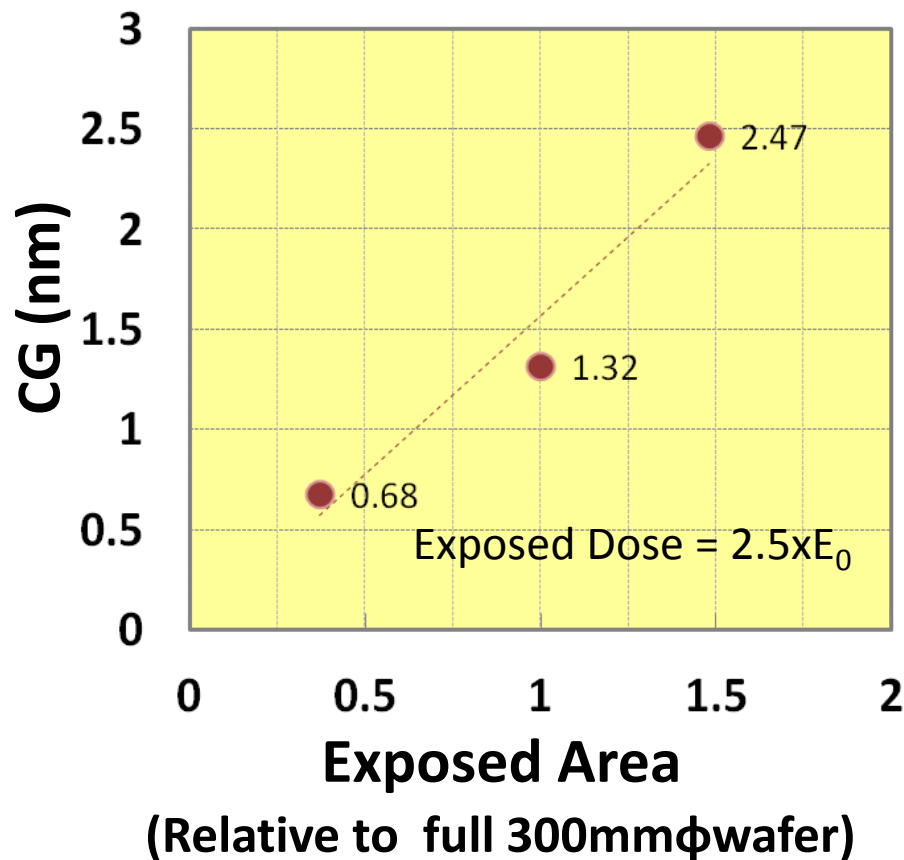
Note : All CG data following this slide are scaled to get to 300 mm full wafer exposure.

■ HERC analysis tool showed good reproducibility (<10%).

CG vs. Exposing Condition (I)

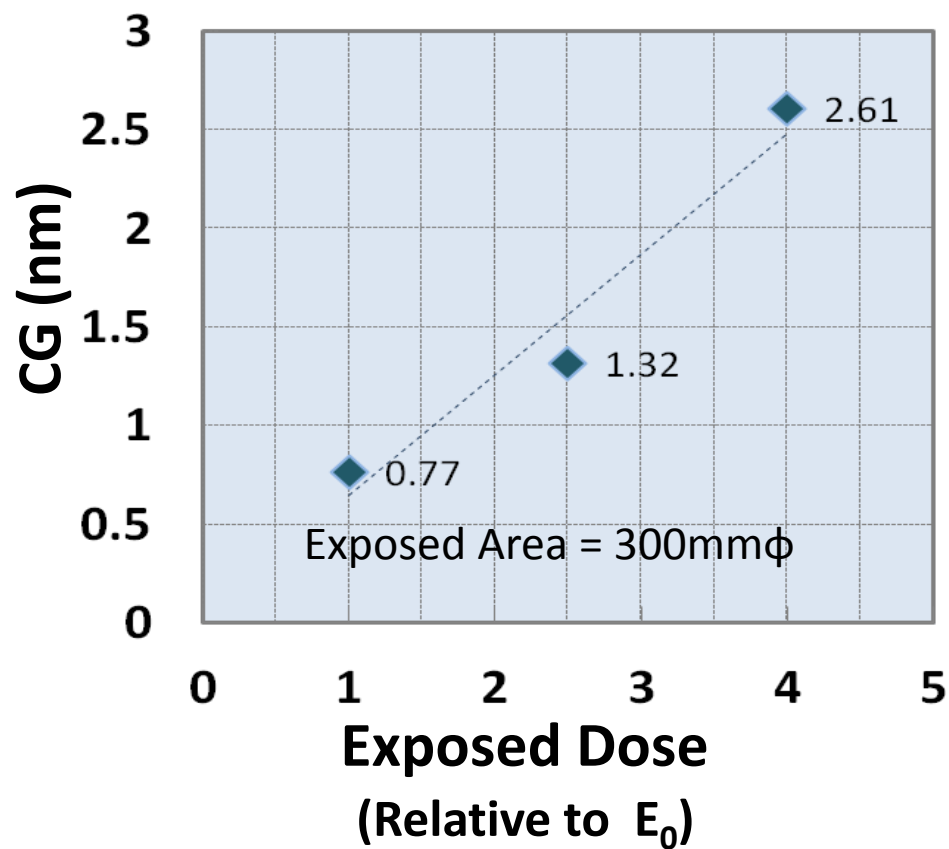
Sample : B

CG vs. Exposure Area



CG \propto Exposure Area

CG vs. Exposure Dose



CG \propto Exposure Dose

CG vs. Exposing Power

Photon Intensity on the WS and wafer

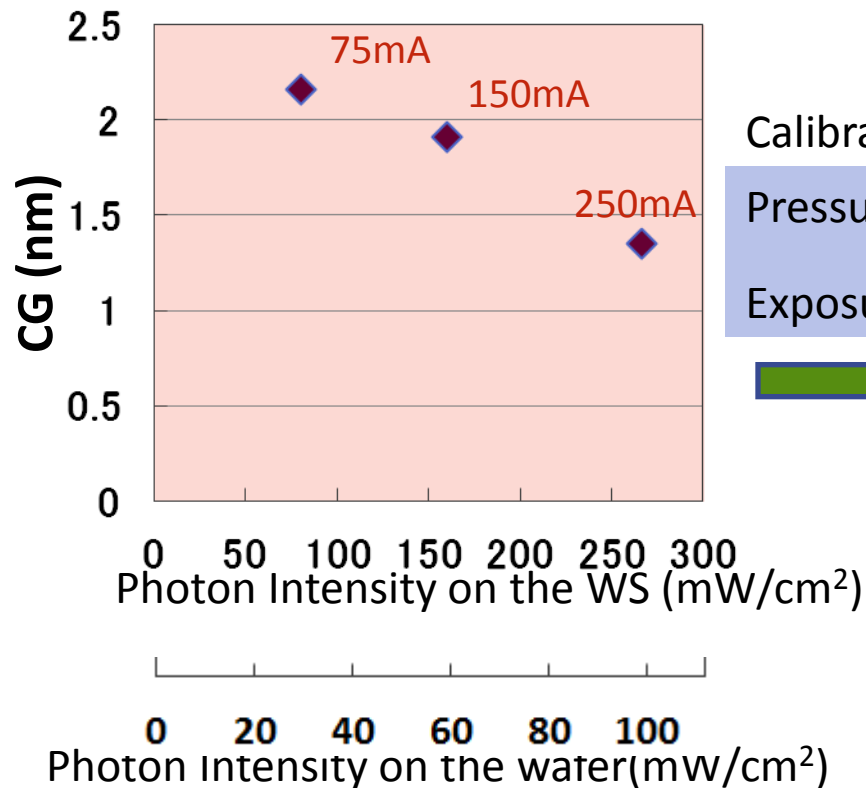
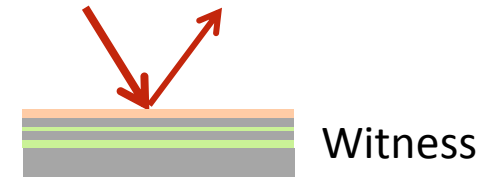
Photon Intensity on the WS and Wafer was changed by changing Newsboy (SR) ring current to 75mA, 150mA, 250mA.

➡ The exposure time also changes for the exposure of 300mmφ area with the dose to resist by $2.5 \times E_0$.

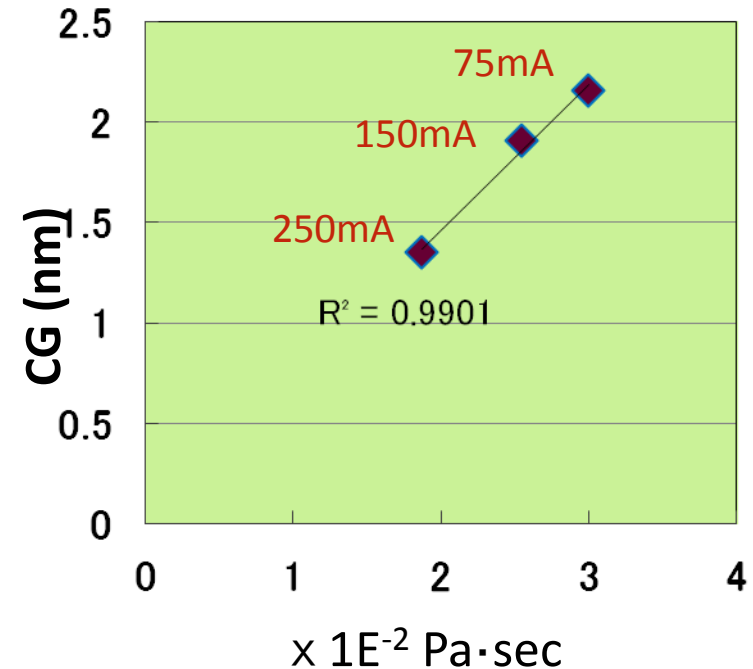
Sample : B

EUV from New
SUBARU

Wafer



Calibrate for
Pressure Rise
x
Exposure Time

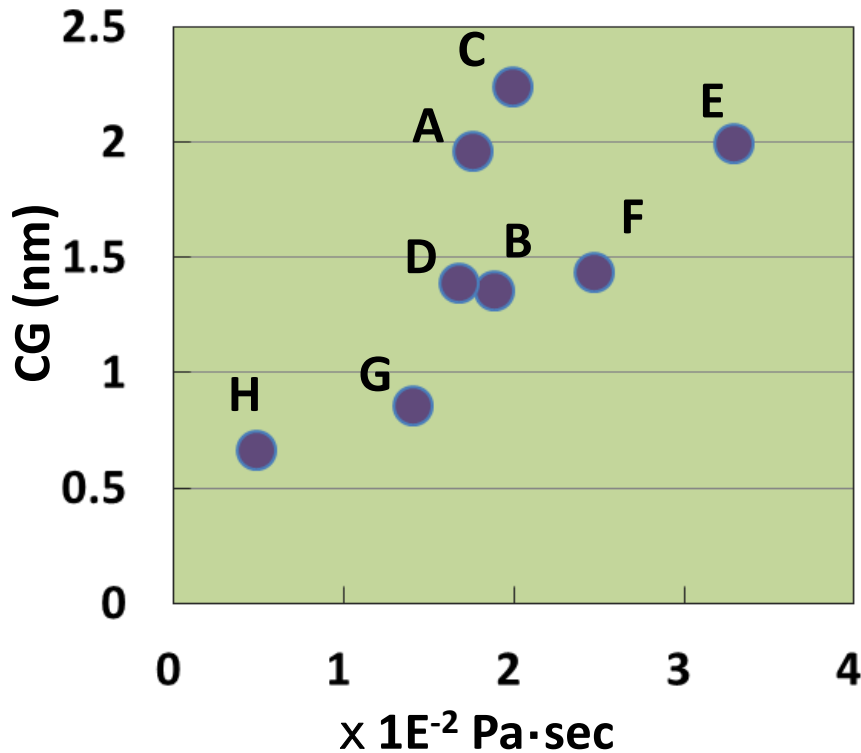


Pressure Rise x Exposure Time

$\text{CG} \propto \text{Pressure Rise} \times \text{Exposure Time}$

CG vs. Resist Components (I)

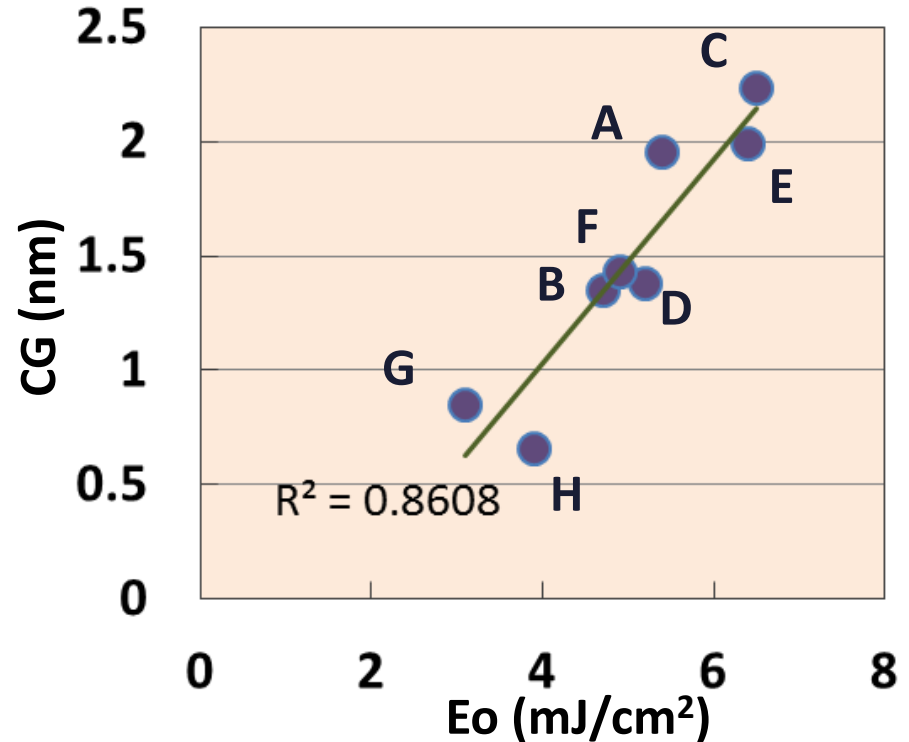
CG vs. Pressure Rise x Time



Pressure Rise x Exposure Time

**Not a good correlation for
Pressure Rise x Exposure Time
among different resists**

CG vs. Resist Sensitivity

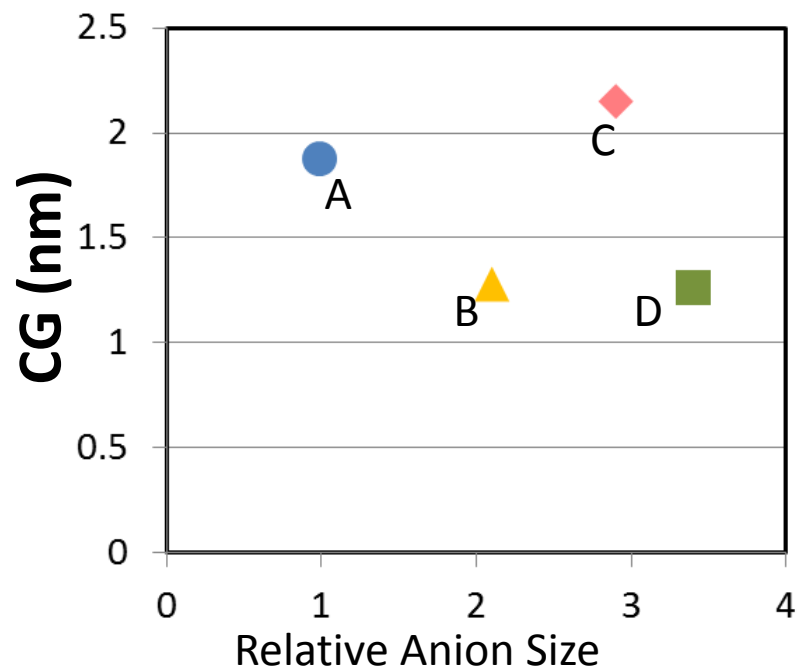


Resist Sensitivity

**High sensitivity samples
resulted in small CG.**

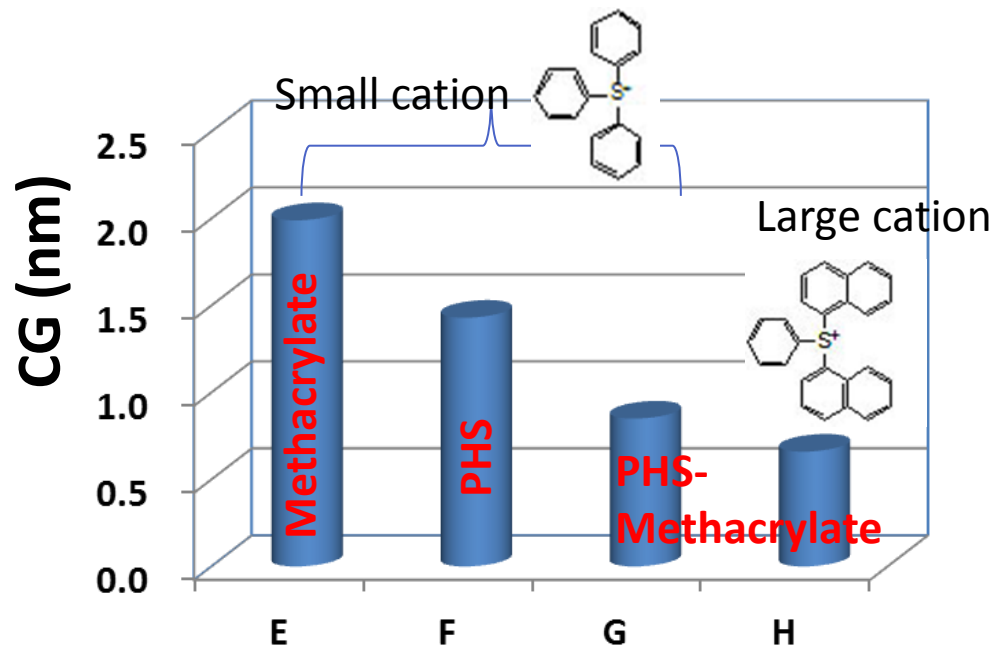
CG vs. Resist Components (II)

Anion size dependency



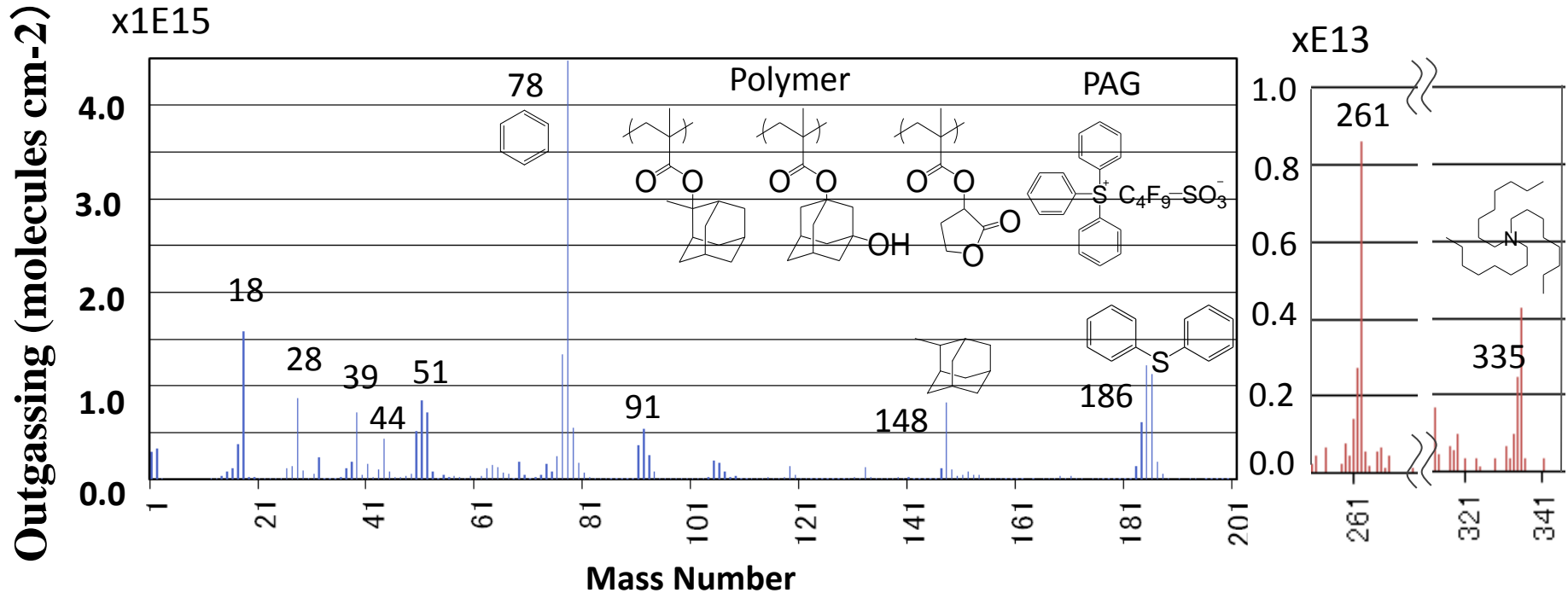
No Dependency

Polymer and Cation dependency

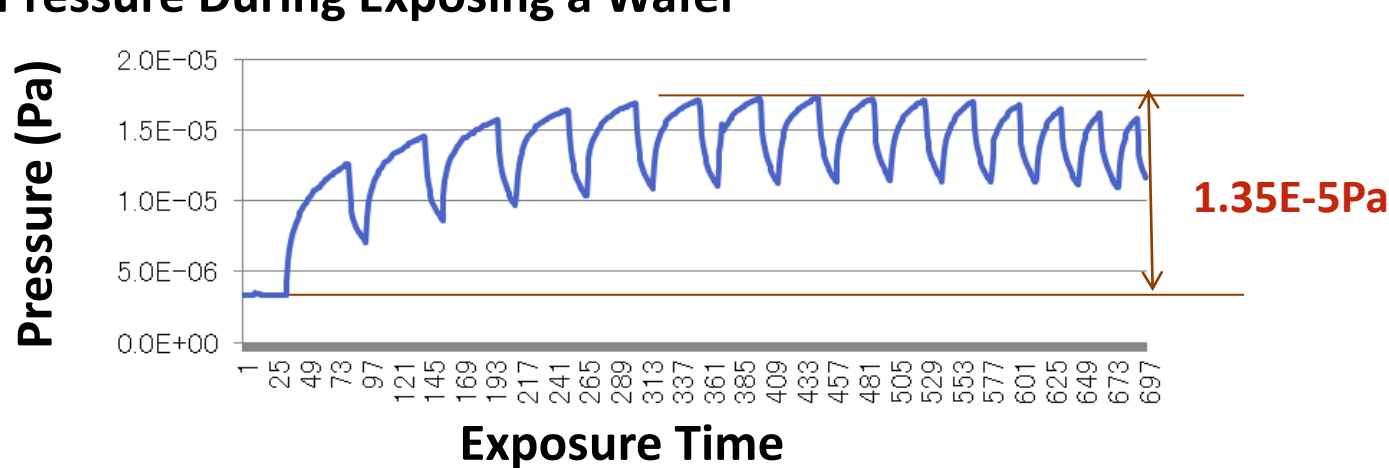


**Influence :
Polymer > Cation**

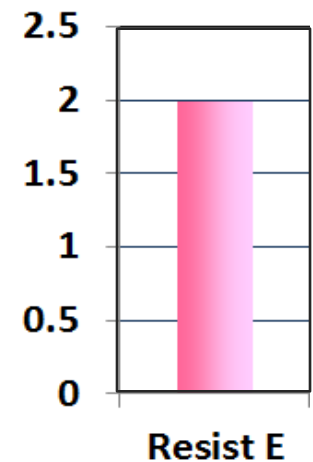
Outgassing Molecular identification of Resist E (Methacrylate)



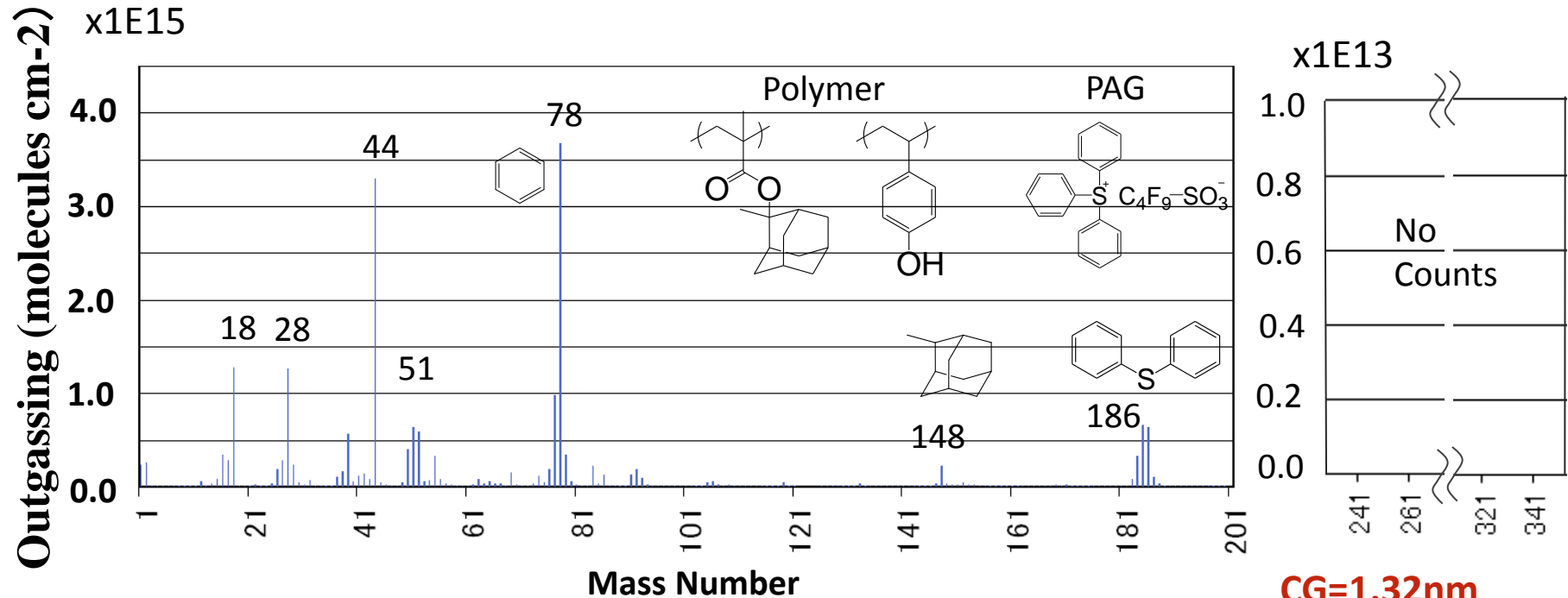
Pressure During Exposing a Wafer



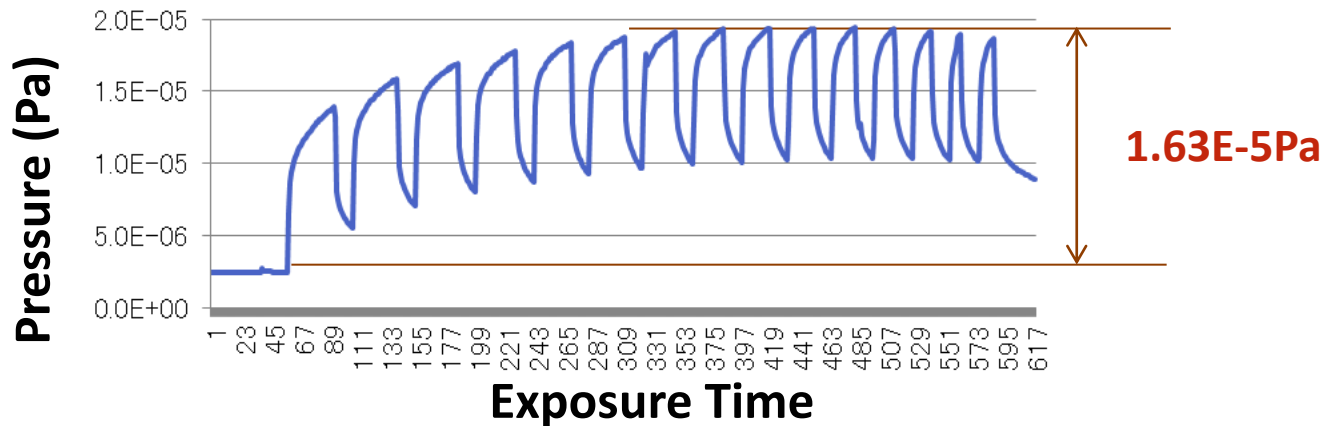
CG=1.99nm



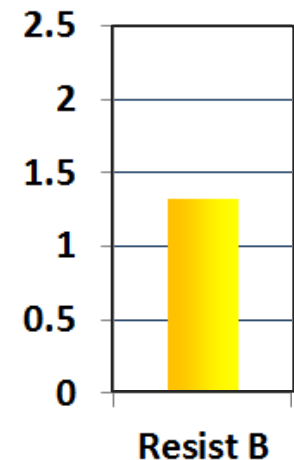
Outgassing Molecular identification of Resist B (PHS-Methacrylate)



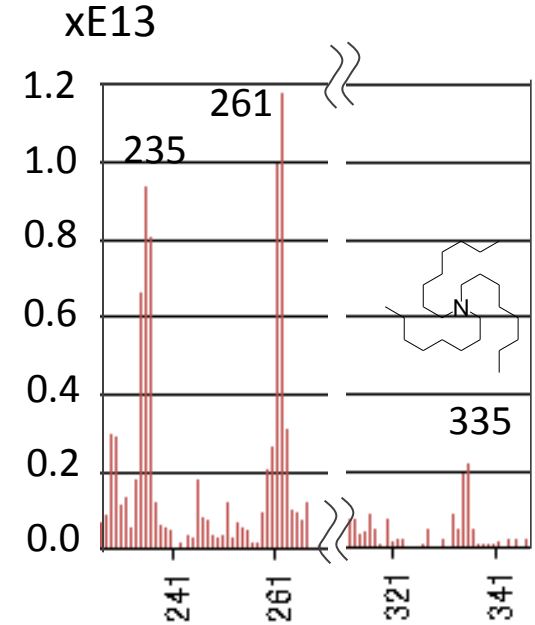
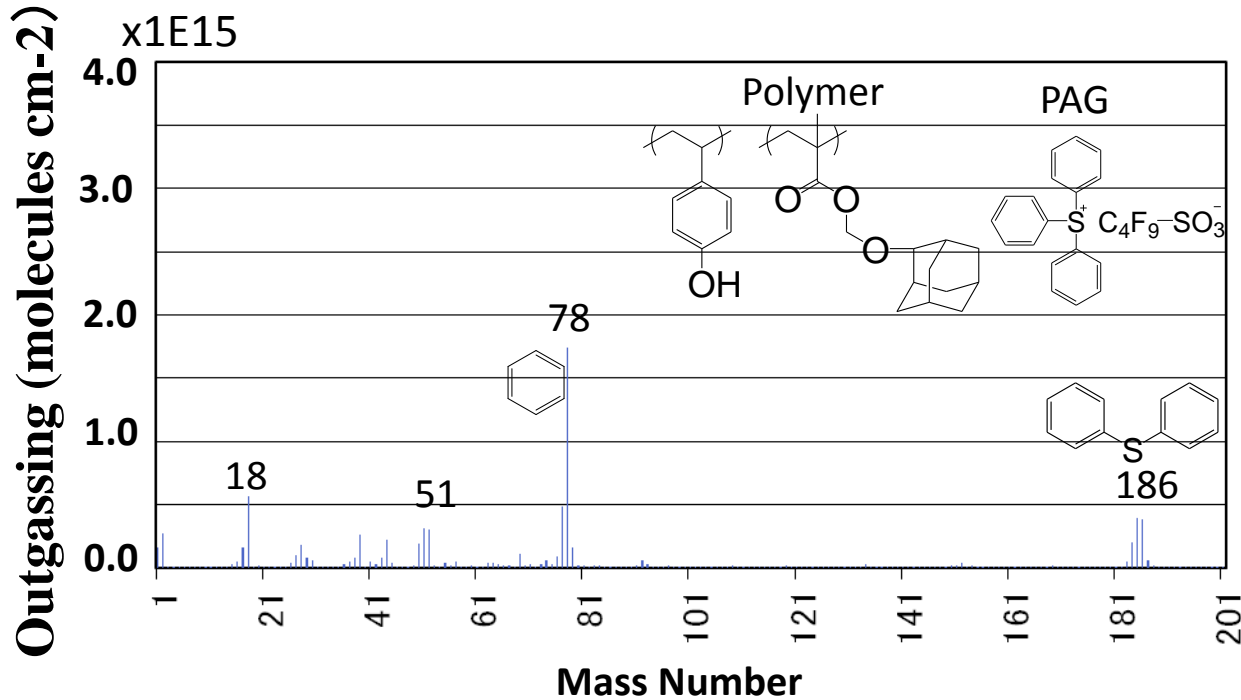
Pressure During Exposing a Wafer



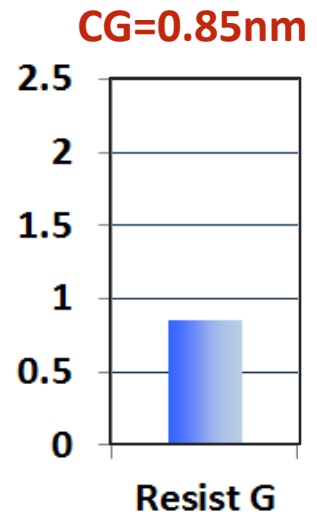
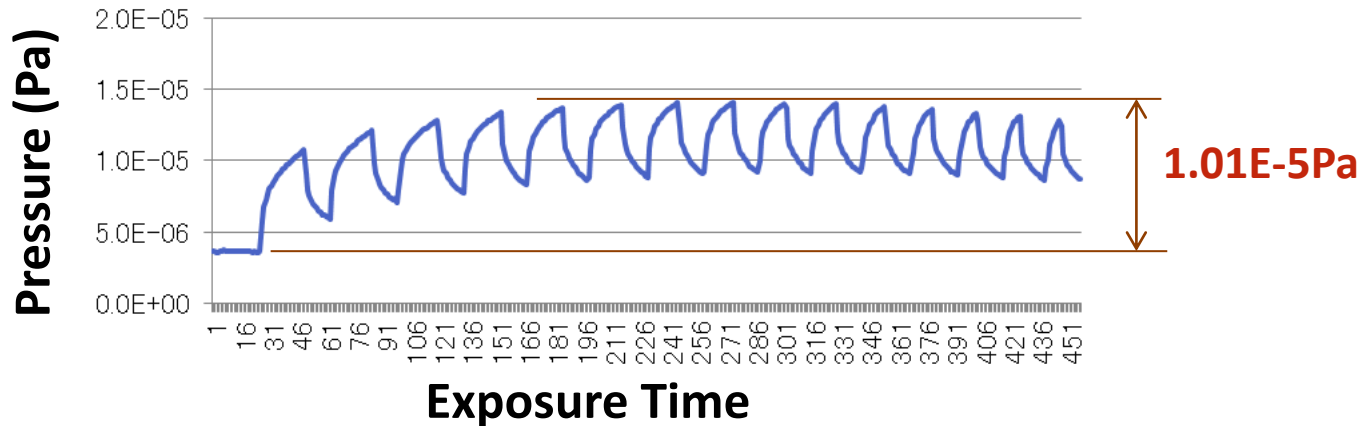
CG=1.32nm



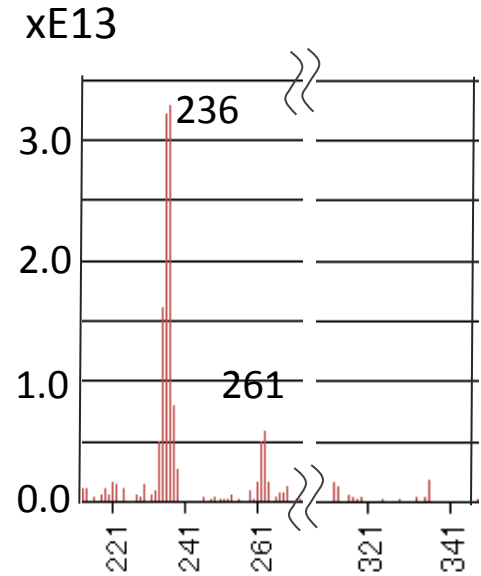
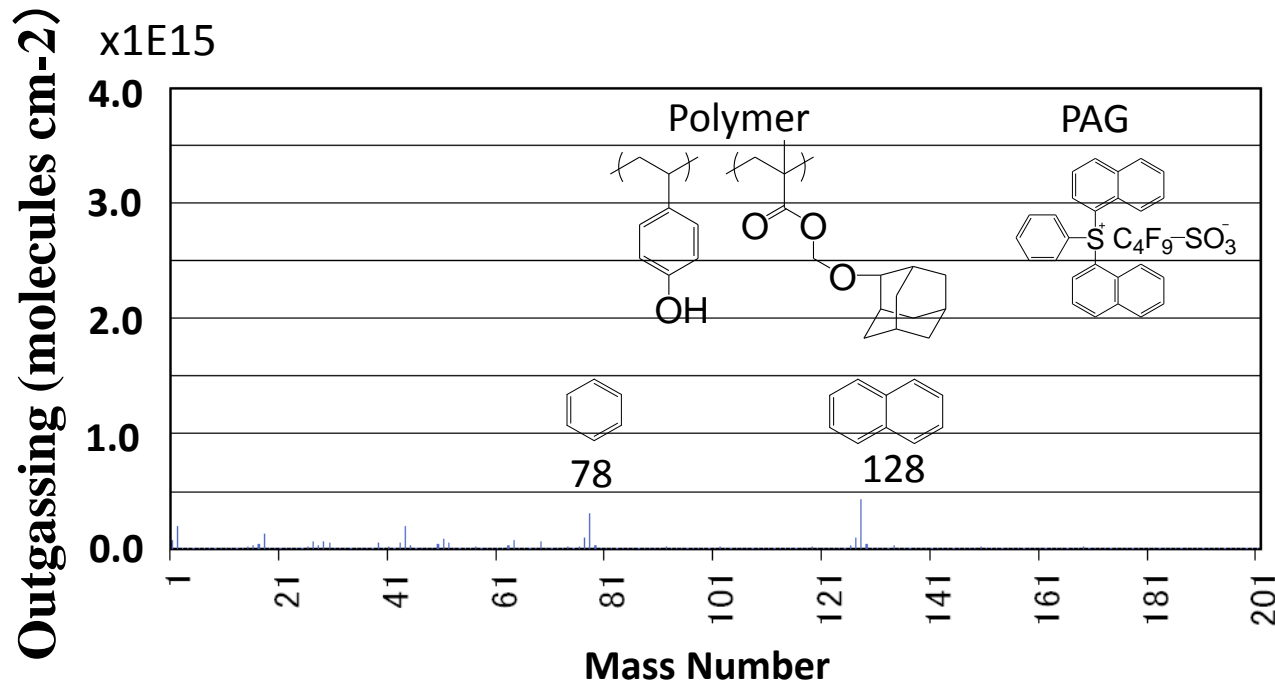
Outgassing Molecular identification of Resist G (w/Small Cation)



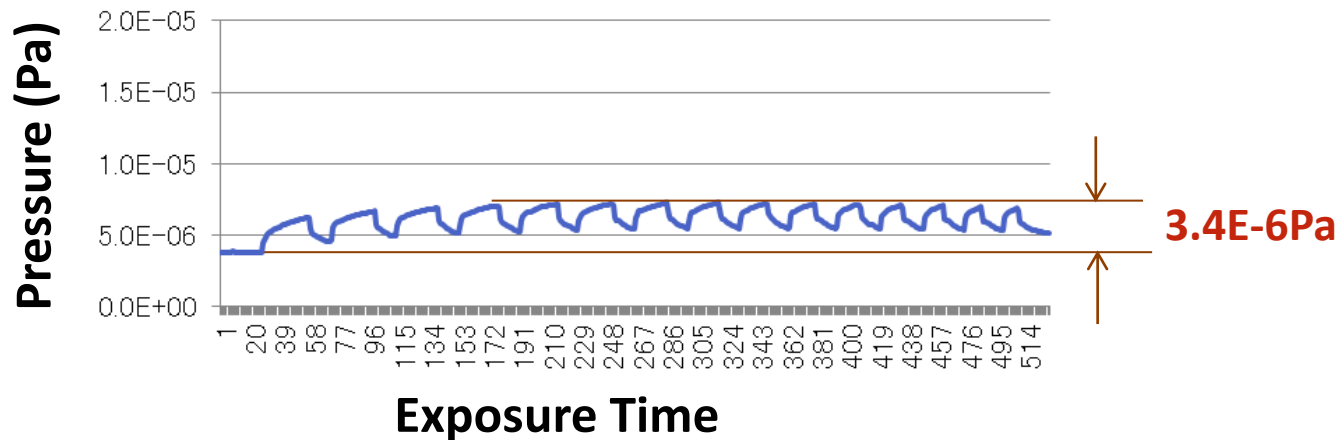
Pressure During Exposing a Wafer



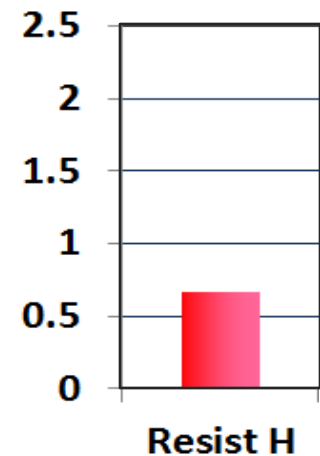
Outgassing Molecular identification of Resist H (w/ Large Cation)



Pressure During Exposing a Wafer



CG=0.66nm



Summary

By using **High power EUV Resist Contamination analysis tool HERC**, the behavior of outgassing contamination growth (CG) on the witness samples (WS) composed of Ru capping layer on the top of the Mo/Si multilayer were studied for various exposure conditions and resist components.

It was found that,

1. The **reproducibility of CG thickness within 10%** was confirmed in HERC.
2. The **Total-pressure-rise x Exposure-time** well corresponded to the CG in the same resist. But among different resist components, this relation did not work good.
3. The **relation of resist components** to CG were examined.

As the results;

Poor correlation for PAG anion size to CG was found.

Correlation for PAG cation size to CG was found.

Correlation for polymer type (or protection group type) to CG was most evident.

4. The **fragments came from PAG cation and protection group** were seen in Mass Spectrum signal taken during the exposure. On the other hand, the fragments from PAG anion were not evident.

Acknowledgement

This work was supported by New Energy and Industrial Technology Development Organization (NEDO).